THE QUESTION OF THE EXISTENCE OF ($\Lambda^\circ P$), (Σ^+P) AND (Σ^-n) HYPERFRAGMENTS

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ABSTRACT. The question of the existence of ($\Lambda^\circ P$), (Σ^+P) and (Σ^-n) hyperfragments has been discussed.

It is not known experimentally whether or not the ($\Lambda^\circ P$), (Σ^+P) and (Σ^-n) hyperfragments exist in the bound state. One possible example each of ($\Lambda^\circ P$) and (Σ^+P) has been reported (George *et al*, 1956 and Baldo-Ceolin *et al*, 1957). If such fragments exist, they are expected to be produced in the interactions of K^- mesons in matter. The possibility of production of ($\Lambda^\circ P$) and (Σ^-n) fragments from K^- interactions with deuterium has been examined in detail by Pais and Treiman (1957). The collinearity of the tracks produced in the reactions

$$K^-+D\rightarrow(\Lambda^\circ P)+\pi^-$$
$$\rightarrow(\Sigma^-n)+\pi^+$$

and their unique ranges would almost certainly identify the ($\Lambda^\circ P$) and (Σ^-n) fragments if produced. Bubble chamber studies of K^- interactions with deuterium have been made (Tripp, 1958); no example of such fragments has been found In the interactions of K^- mesons with the more complex nuclei of emulsion, however, identification of these fragments, if produced, is not easy and would need measurements of mass to be made on all tracks produced in K^- stars including the short and black ones. Such measurements are not generally carried out mainly due to the fact that, in most cases, mass measurements on short black tracks are not very reliable. Identification of such tracks from K^- stars in emulsion is often based on the characteristics of the end of the track. We should examine, therefore, the possible end characteristics of the ($\Lambda^\circ P$), (Σ^+P), (Σ^-n) fragments to see if they could be confused with other known particles.

$\Lambda^\circ P$:—The ($\Lambda^\circ P$) can decay according to the following modes :

$$(\Lambda^\circ P)\rightarrow P+P+\pi^-+37.0\text{ MeV *} \quad \ldots (1)$$
$$\rightarrow P+n+\pi^\circ+40.3\text{ ,,} \quad \ldots (2)$$

* In calculating the Q-values, the values of the masses have been taken from Cohen *et al* (1957) and the unknown binding energies have been ignored.

$$\rightarrow D+\pi^{\circ} \quad +42.5 \quad \text{MeV} \qquad \ldots \quad (3)$$

$$\rightarrow P+n \quad +175.3 \quad ,, \qquad \ldots \quad (4)$$

In (1), the $(\Lambda^{\circ}P)$ can be confused with H^3 hyperfragment decaying according to the process $\Lambda H^3 \rightarrow D+P+\pi^-$. It was pointed out by Telegdi (1957) in his survey of hyperfragments that certain examples of ΛH^3 hyperfragment in his sample could also well be $(\Lambda^{\circ}P)$. In (2), the energy of the charged product, the proton, could lie anywhere between 0 and 40 MeV. In this case the $(\Lambda^{\circ}P)$ might be classed as a Σ^- hyperon producing a one prong capture star from rest. The same is true with the decay-mode (3) where the charged product, the deuteron, will have an energy of approximately 1.5 MeV and a range in emulsion of 20μ. In (4), the proton will have an energy of approximately 88 MeV. This may be erroneously classified as an example of Σ^- capture star in which the Λ° has been trapped and decayed inside the nucleus (Goldsack and Lock, 1956) or as a heavy hyperfragment decaying non-mesonically.

Σ^+P :— The (Σ^+P) can decay according to the following modes :

$$(\Sigma^+P) \rightarrow P+n+\pi^+ + 110.6 \text{ MeV} \qquad \ldots \quad (5)$$

$$\rightarrow P+P+\pi^{\circ} + 116.5 \quad ,, \qquad \ldots \quad (6)$$

$$\rightarrow D+\pi^+ + 112.8 \quad ,, \qquad \ldots \quad (7)$$

$$\rightarrow P+P+251.5 \quad ,, \qquad \ldots \quad (8)$$

In (5), the appearance of the (Σ^+P) track ending is confusable with the mesonic decay of a Λ°-hyperfragment. In (6), the (Σ^+P) decay may be confused with a Σ^- capture star with two prongs or a hyperfragment non-mesonic decay if the charged decay products are energetic. In (7), the deuteron will have an energy of approximately 8.3 MeV and a range in emulsion of 245μ while the pion will have an energy of about 104.5 MeV. Although this decay mode would be very easy to identify owing to the collinearity of the deuteron and pion tracks, the high energy pion track may be missed in some cases and the event recorded as a Σ^- capture star. The decay-mode (8) is very difficult to miss if it occurs.

In all the three-body decay modes (1), (2), (5) and (6), if one of the charged particles, say the proton, is emitted with an energy less than a certain minimum energy (0.2 MeV for emulsion) the track would not be visible. In such cases (5) and (6) would appear to be normal Σ^+ decays.

Σ^-n :— The (Σ^-n) can decay in flight only; on coming to rest it will be captured like a Σ^- hyperon and would be indistinguishable from the latter in its star characteristics.

The decay-mode in fllight will be

$$(\Sigma^-n) \rightarrow n+n+\pi^- + 117.6 \text{ MeV} \qquad \ldots \quad (9)$$

Unless the high energy pion is followed to its end and its energy (and sign of charge) determined, the decay (9) will appear to be an example of Σ^+ or Σ^- hyperon decaying in flight. White *et al* (1958) have followed to rest several lightly ionizing tracks from $\Sigma\pm$ hyperon decays in flight. They have found no example of a π-meson of an anomalous range.

An unknown contamination of (Σ^-n) fragments in a sample of $\Sigma\pm$ hyperons decaying in flight would tend to make the apparent lifetime of these hyperons shorter than the actual value since, for the same measured values of β at the points of emission and of decay, the calculated time of flight would be smaller than the actual time if a smaller value for the mass is used in the calculation. The lifetime of $\Sigma\pm$ hyperons decaying in flight has been measured in emulsion by several groups of workers In each of these measurements, the assumption has been made that the sample of $\Sigma\pm$ hyperons consists only of Σ^+ and Σ^- hyperons. The results on lifetime obtained by these different groups do not agree among one another; some groups (Freden *et al*, 1958, Fry, 1957 and Glasser, 1957) report a value for the lifetime of $\sim 0.5\times10^{-10}$ second which is shorter than the lifetime of either Σ^+ $(0.86\times10^{-10}$ second) or $\Sigma^-(1.83\times10^{-10}$ second) hyperons (Cohen *et al*, 1957) thus indicating the presence of some other effect such as the above-mentioned one; other groups (K^-stack collaboration, 1957 and Goldhaber 1957) report a value for the lifetime of $0.8-0.9\times10^{-10}$ second which, although being higher than the previous result, is much lower than the Σ^- lifetime.

It has been pointed out by Snow (1958) that for a certain binding energy region close to zero the (Σ^-n) fragment may be bound, while the (Σ^+P) is unbound due to the extra repulsive force in case of the latter

The considerations made above show that very careful analysis of K^-stars in emulsion is needed to distinguish the mass-2 hyperfragments from other known particles if such fragments exist and are produced in K^- interactions. The fact that no example of Σ^-n fragments and only one example of (ΛP) and (Σ^+P) has been reported so far, therefore, does not necessarily mean the non-existence of these fragments.

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